

Developing e-Bug web games to teach microbiology

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As a complement to the e-Bug teaching pack, two e-Bug games were developed to provide content that aimed to entertain as well as to educate. A set of agreed learning outcomes (LOs) were provided by the scientific partners of the e-Bug Project and the games were developed using user-centred design techniques (the needs, wants and limitations of the potential game players were assessed at each stage of the design process). The e-Bug games were designed for two age groups: Junior (9 – 12 year olds); and Senior (13 – 15 year olds).

A study using focus groups was done to gain an understanding as to the types of games enjoyed by the target users. According to the preliminary study, the Junior Game was developed as a platform game and the Senior Game was developed as a story-based detective game. The Junior Game consists of five levels, each associated with a set of LOs. Similarly, the Senior Game consists of four missions, each comprising five stages using problem-based learning techniques and LOs. In this paper, the process of development for each game is described in detail and an illustration is provided of how each game level or mission addresses the target LOs.

Development of the games used feedback acquired from children in four schools across the UK (Glasgow, London and two in Gloucester). The children were selected according to their willingness to participate. European Partners of the e-Bug Project also provided further support, translation and requests for modifications. The knowledge gained of LOs and further evaluation of the games is continuing, and preliminary results are in press. The final versions of the games, translated into 11 European languages, are available online via www.e-bug.eu.

Keywords: antibiotic resistance, hand washing, education web games, Internet intervention, problem-based learning (PBL)

Introduction

In addition to the e-Bug school teaching pack, two e-Bug games were developed, providing content suitable for children, and covering microbes, hygiene and the appropriate use of antibiotics. Both games aim to entertain as well as to educate the young people who play them. The games were a Junior Game (for 9 – 12 year olds) and a Senior Game (for 13 – 15 year olds). Common

learning outcomes (LOs) were agreed by the scientific partners of the e-Bug project pack and web site, and the

games were developed using user-centred design techniques (the needs, wants and limitations of the potential game players were assessed at each stage of the design process). Each game uses a different pedagogy (strategy of instruction) to teach its content and provides

very different playing experiences. This paper discusses the approach used to develop these games. We used a standard iterative software development methodology. The actual development involved gathering user requirements and using design techniques such that the players were placed at the centre of each game's design.

Involving children in every stage of the development process is also referred to as user-centred design in this article.

Developing the games

Hardware and software platforms

Games software is typically distributed via CD-ROM or via the Internet. Games software provided on CD-ROM is typically compatible with only one operating system (e.g. Windows, Mac, Linux), and requires that physical media be created and distributed to every player who is interested in playing. Web browser games, on the other hand, are usually playable without any requisite installation of administrative rights. Furthermore, multiple physical copies of the games software are not needed if more than one player wants to play (and download the game).

If a suitable web gaming platform is chosen, the games are also playable across most operating systems. For these reasons, it was decided that the e-Bug games would be hosted on the e-Bug web site and be playable through a web browser.

In order for the games to be playable by as many European children as possible, it was necessary to assess the availability of computers and Broadband Internet to classrooms in each partner country. The e-Bug partners were asked to fill in a questionnaire that provided these data about their own country. All countries reported a high accessibility to computers $\geq 80\%$ at the Junior and Senior school levels. Poland reported the lowest accessibility [70% (junior schools) and 79% (senior schools)]. The range of schools with broadband access varied considerably between countries, with Greece relying largely on dial-up connections. This research took place in 2006 and while we expected the accessibility and broadband situation to improve in future, the data were instructive in choosing how to design the e-Bug games. Figure 1 shows Internet access for 7 of the 11 participating countries. An attempt was made to identify the technical capabilities of these computers, but it was not possible to determine this. The games were therefore designed to be suitable even for low-specification computers.

A number of software technologies were considered for delivering the web-based games, but only Flash (Macromedia, Inc.) has sufficient market coverage to be readily available. A 2007

survey by Millward Brown for Adobe.com found that Flash Version 8 had a market penetration of 95.1% by March 2007.¹ Flash is the technology used to power sites such as YouTube and is currently at Version 10; however, Version 8 was chosen to ensure that even older computers would be able to play the games. If a newer version of Flash (or an alternative technology) was required, it might be necessary for teachers to request administrative rights to their computers in order to install the web browser plug-in.

Contexts in which the games would be played

Early in the process, a focus group with five senior-school teachers (chosen for convenience) was held in Gloucester. They were asked how they would use games in the classroom and a number of situations were considered to be suitable for using a game, such as: an introduction to a topic; a summarizing activity at the end of a topic; a task for a child who finished a task early; or a piece of homework. No one scenario seemed to be dominant—teachers said that they would use games in the classroom when it was suitable on a case-by-case basis. Because of the difficulty in arranging the use of dedicated computer rooms for a class, and in order to increase the likelihood of the games being played by children out of class, it was decided that the games would stand independently of the e-Bug pack (as opposed to being mini-games associated with each lesson, as the original idea had been) and would aim to be as entertaining as possible for children to help them compete with other web-based entertainment. This would also extend the interest in the games for children not being taught e-Bug at school but who found the games online. The uptake of online users confirmed this approach to be correct.

Genres of play

Focus groups were held with a small number of children ($n=6$, junior age group; and $n=15$, senior age group) in Glasgow in 2007 (a convenience sample), to find out what kind of games they enjoyed. This was complemented by a computer games market study to evaluate the popularity of current commercial games, in which we looked at the sales charts provided by the games industry magazine *Develop* in the UK and the various international Amazon web sites.

Junior Game

Children in the younger age group expressed a liking for simple games, such as *Super Mario Brothers* (from Nintendo) and those found on web sites such as Kongregate.com. Most of these games are simple and require no training before use. It was decided after looking at these games and speaking to the

children that a platform game (similar to the *Super Mario Brothers* series) would be an enjoyable play experience for this age

European schools (in 2006).

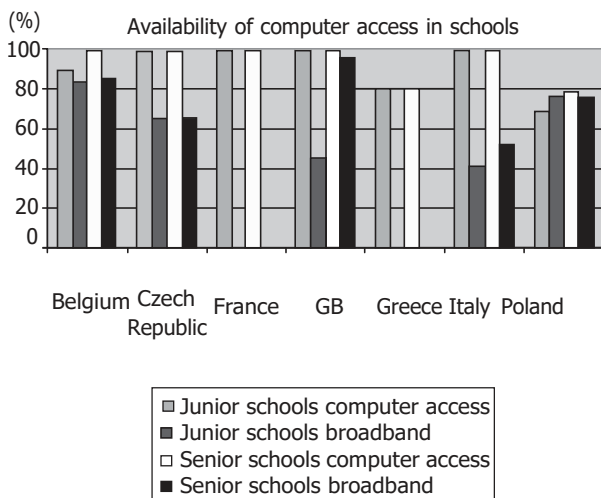


Figure 1. The reported availability of computer and Internet access in

group.

Senior Game

The older children had stronger opinions on the type of games they enjoyed. The most commonly mentioned genres were games that involved sports, racing and shooting. As these were

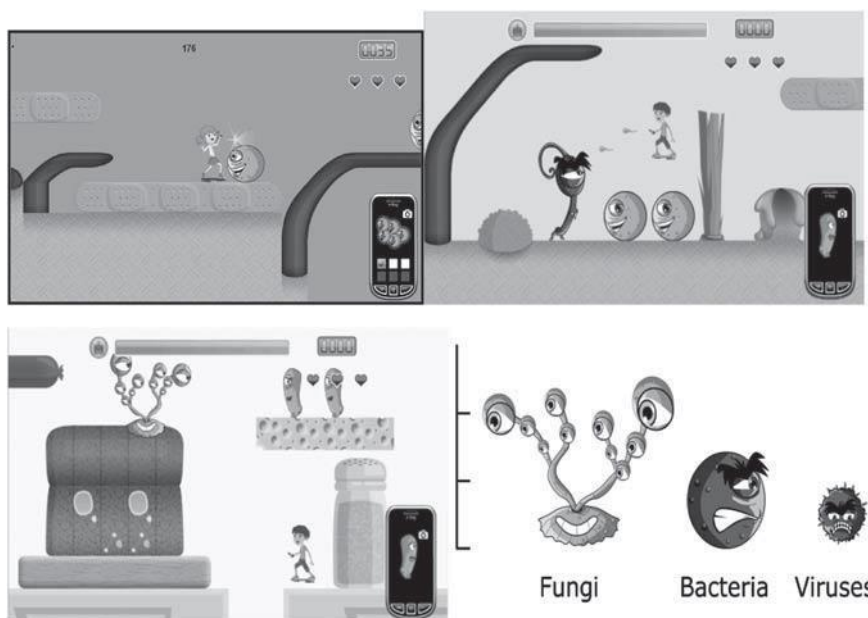


Figure 2. Snapshots of the Junior Game—Level 1 action. The player takes a photograph of ‘Steve Staphylococcus’ (top left); microbes are found on the surface of the human skin (top right) and in the kitchen (bottom left); and microbes are shown in various shapes and sizes (bottom right).

unsuitable for e-Bug, further discussion elicited other types of games that they had enjoyed. Two children mentioned story-based adventure games, such as *Broken Sword*² or the *Phoenix Wright: Ace Attorney* series.³ In a follow-up session, these children were given commercial games of this type to play and they all enjoyed the experience with responses ranging from ‘I love this kind of game’ to ‘I wouldn’t mind playing it’. Therefore, a story-based play experience similar to the *Phoenix Wright* game was chosen as an appropriate genre for the Senior Game.

Teaching through play: identifying suitable teaching methods

In order to avoid what Habgood calls ‘chocolate-covered broccoli’,⁴ where a game offers no educational benefit beyond extrinsic motivation, it is necessary to integrate learning through game mechanics. Unfortunately, games-based learning (GBL) research in its infancy and effective methods harnessing the learning that happens in games have not yet been sufficiently investigated.⁵

Junior Game

A platform game is both highly interactive and quick to respond to user actions. Work by Squire⁶ and Svarovsky and Shaffer⁷ has shown that these types of games can offer a deep and meaningful learning experience. Svarovsky and Shaffer in particular offer the concept of an *exploroid*, or ‘short fragments of exploratory action in a microworld that cumulatively develop interest in and understanding of important scientific concepts’. This concept was used for the Junior Game, where the player is offered opportunities to interact with microbes and see the consequences of their actions.

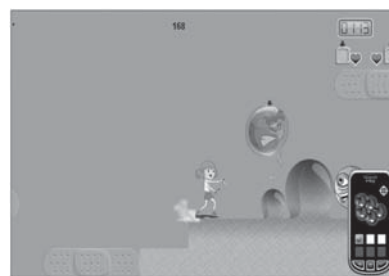


Figure 3. Snapshot of the Junior Game—Level 2 action. The player has thrown soap at a harmful microbe, which is floating away inside a bubble.

Senior Game

Adventure games are largely story driven and because stories require a lot of text, it would be difficult to have the Senior Game allowing the player the interactive, iterative experience that is possible in a simple platform game. As such, an alternative pedagogy was sought. Problem-based learning (PBL) is ‘any learning environment in which the problem drives the learning. That is, before students learn some knowledge they are given a problem’.⁸ By posing a problem before any learning takes place, children are able to contextualize new knowledge instead of simply learning stand-alone facts. PBL encourages independent learning with minimal intervention from a teacher. Used extensively in medical training in higher education, PBL can be adapted to teach a wide range of LOs, making it suitable for e-Bug. There have been a number of studies on the effectiveness of PBL and, whilst there is no conclusive evidence that PBL is preferable to other successful methods of teaching, it has been shown to be effective.⁹ Some research has suggested that PBL is a natural approach to GBL,¹⁰ but there has been little empirical evaluation to date. Picard found that using PBL in a business game had a

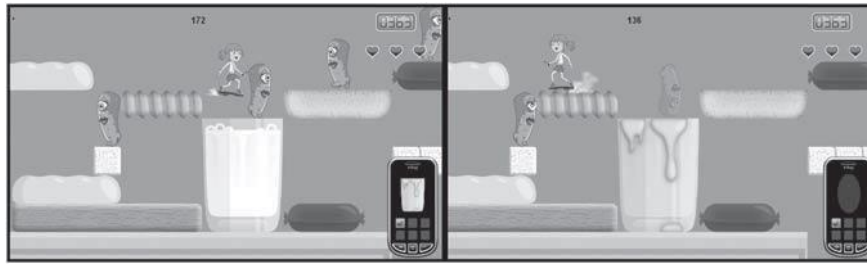


Figure 4. Snapshots of the Junior Game—Level 3 action. The player uses a *Lactobacillus* bacterium to convert milk (left) into yogurt (right).

positive effect on university students in terms of satisfaction and attainment.¹¹ A recent study using a PBL-based game in senior school found that children were successfully engaged, but the difference in knowledge gain between intervention and control groups was not significant.¹² Whilst the evidence supporting PBL's use in GBL is not conclusive, the concepts behind PBL map very well onto the core game mechanics of adventure games. Given the lack of a clearly established pedagogy to support this type of game, and considering the wide remit of e-Bug and the flexibility that is required to cover all LOs, it was decided to use PBL to underpin the Senior Game's teaching.

Design mechanics

Junior Game

In order to facilitate teaching the LOs, the player chooses an avatar that is shrunk to the size of a bacterium and then uses a hoverboard to move around various environments that microbes inhabit. In total, there are five levels to the game, each with its own focus (LOs) and rules.

Level 1: Introduction to Microbes The player is introduced to the general game structures—such as how to move the avatar and how to exit the level. The LOs are 3-fold: (i) bacteria, viruses and fungi are three different types of microbe; (ii) microbes are found everywhere; and (iii) microbes come in different shapes and sizes. The player is tasked with taking photographs of one type of microbe at a time and is not rewarded when taking photographs of the 'wrong' type of microbe (Figure 2). The player is shown that microbes are 'everywhere' by visiting two common locations where microbes exist: on the human skin and in the kitchen. The in-game artwork depicts microbes as cartoons, drawn according to their real-life counterparts (i.e. size and shape). For example, fungi are shown to be larger than bacteria, which in turn are shown to be larger than viruses.

Level 2: Harmful Microbes The player encounters microbes whose 'harmful' nature is represented in three game mechanics. Firstly, if a 'good' and a 'bad' microbe touch each other, they both die and are removed from the game. Secondly, if the player touches a harmful microbe, they suffer the loss of one life. Thirdly, if the player loses three lives, they must restart this level. Lastly, good microbes are smiling, and bad microbes have evil eyes and bared teeth. The player can combat the harmful microbes; e.g. they can throw soap at a microbe in the kitchen or on the skin, and the microbe becomes enveloped in



Figure 5. Snapshot of the Junior Game—Level 4 action. The player places the recently bought shopping items into their appropriate places in the kitchen.



Figure 6. Snapshot of the Junior Game—Level 5 action. The player delivers a full course of antibiotics to the bacterial infection.

the soap bubble and floats away (Figure 3). Also, they can throw white blood cells at the microbe whilst in the body and the harmful microbe is destroyed. The LOs are 3-fold, including: (i) sometimes microbes can make us ill; (ii) washing can prevent the spread of infection; and (iii) our bodies have defences to fight off infection.

Level 3: Useful Microbes The LOs are 2-fold, including: (i) not all microbes are harmful; and (ii) useful microbes can make things like bread and yogurt. The player can actually push a 'Lucy Lactobacillus' bacterium into a glass of milk to create yogurt (Figure 4).

Level 4: Hygiene When the player moves into the kitchen, they change from their shrunken state to their full height, and must put shopping away in a fridge and cupboards, ensuring they wash their hands after handling meat and placing each item in an appropriate place to prevent contamination (Figure 5). If the avatar sneezes, the player must use a tissue to catch the sneeze, throw the tissue away and then wash their hands before continuing with the level. The LOs are 5-fold, including: (i) infection can



Figure 7. Snapshots of the Senior Game. The player meets the bodyguard (left) and explores the kitchen (middle) using Microbe Vision (right).

spread through unclean hands; (ii) hand washing can prevent the spread of infection; (iii) microbes found on food can pass to humans; (iv) cooking food properly can kill harmful microbes; and (v) sneezing or coughing in your hand can still spread infection. Respiratory and hand hygiene, and appropriate food handling and food storage are all discussed here.

Level 5: Antibiotics The player returns to her/his shrunken state to tackle issues about antibiotics. The learning outcomes are 2-fold: (i) sometimes it is necessary to take antibiotics; and (ii) if antibiotics are taken, it is important to finish the course. The player uses an antibiotic as a 'smart bomb' effect, whereby both good and bad bacteria are killed, but not viruses (Figure 6). The player is shown how a serious infection returns after initially appearing eradicated, following a partial antibiotic course. The infection is only fully eradicated by using the remainder of the antibiotic treatment.

Senior Game

The senior game is a story-based adventure and therefore it uses the same basic method (PBL approach) to implement all LOs. For each LO, a situation is designed that requires the user to speak to characters, look for evidence and identify the solution to problems that elicit an understanding of the LO.

The application of the five stages of PBL vary between implementations; however, for e-Bug, the Queen's University (Kingston, Ontario, Canada) definition was utilized.¹³ Using this definition, Stage 1 is the *Topic Introduction*, allowing the facilitator to introduce the topic and highlight why the topic is relevant. In Stage 2, students write the *Problem Statement* in their own words and care is taken to ensure that they correctly understand the problem. In Stage 3, the students *Hypothesize* potential solutions to the problem and identify one to pursue. In Stage 4, the students carry out *Research*—seeking information that confirms or refutes their hypothesis. In Stage 5, students consider whether their hypothesis is confirmed through evidence—and if so, they *Present their Result* or findings with an emphasis on methodology, rather than the final answer. If the hypothesis is proved incorrect, students return to Stage 3 and identify a new hypothesis to investigate.

The Senior Game is divided into four missions, each of which covers related LOs and presents the player with an overall problem. The player does not have the information required to solve the problem and must therefore solve multiple subproblems first. Similarly, each subproblem covers other LOs and may be further divided. In the following example we will look

at how the game delivers three LOs, with the player having been asked to investigate why an actor has fallen ill. The LOs include: (i) different types of microbes are found in different places; (ii) microbes can be found on our food and can transfer to humans; and (iii) separate chopping boards should be used for meat and vegetables.

Stage 1: Topic Introduction Non-player characters (NPCs) use dialogue to describe the initial problem. Here, an actor has fallen ill and his bodyguard suspects foul play. The overall problem is to identify the cause of his illness.

Stage 2: Problem Statement The actor's bodyguard (see Figure 7) offers theories that may explain the illness. One such hypothesis is that the chef deliberately poisoned the actor. Another theory suggests that poor food hygiene is responsible.

Stage 3: Hypothesis In order to solve the problem, the player has to investigate one of the hypotheses. If the player switches on 'Microbe Vision', she/he can identify potential evidence that may suggest which of these is most suitable (Figure 7). Relevant to the food hygiene hypothesis are evidence of microbial concentrations on the actor's leftover food as well as the chopping board in the kitchen.

Stage 4: Research Having decided to pursue the food hygiene hypothesis, the player may speak to NPCs, visit locations, and collect and test evidence. If the player tests the chopping board and food leftovers, an NPC passes information to the player, teaching the desired LOs. For example, when the player tests the chopping board, *Campylobacter* is present. The player is told that this is normal for chopping boards used for meat. If the player tests the leftovers, she is informed that the chicken is clear of microbes (it was properly cooked) but that the salad is contaminated with *Escherichia coli* and norovirus.

Stage 5: Presenting Results During dialogue with NPCs, the player has the option to present an item of evidence in response to a statement. By showing evidence that the microbes on the plate are of a different type than those on the chopping board, the player disproves the bodyguard's hypothesis and completes the problem.

Conclusions

The e-Bug Junior and Senior Games act as stand-alone companions to the e-Bug teaching packs. Playable by children at home, or within the classroom, they offer an engaging and entertaining way for children to gain knowledge of learning outcomes related to microbiology. Each game was designed to have a genre and style of play appropriate for the target user group, and a suitable pedagogical model was used for teaching in each game. By engaging with play-testers frequently (in keeping with the methodology of user-centred design techniques), it was possible to iteratively develop games that ensured player satisfaction. Although a game may be designed on paper, the experience of play is impossible to assess without testing the game with users. Throughout development, frequent developmental evaluations using play-tests, focus groups and observational studies were used to test new features and to ensure that the games would be enjoyed by children. Quantitative and qualitative evaluations of the games are ongoing and in press.^{14,15} The final versions of the games have been translated into 11 European languages using support, translation and modification requests from the e-Bug partners throughout the course of the project. The e-Bug games are accessible online via www.e-bug.eu.

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